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STATEWIDE MORTALITY OF PONDEROSA PINE CAUSED BY MOUNTAIN PINE BEETLE FOR MONTANA IN 1980

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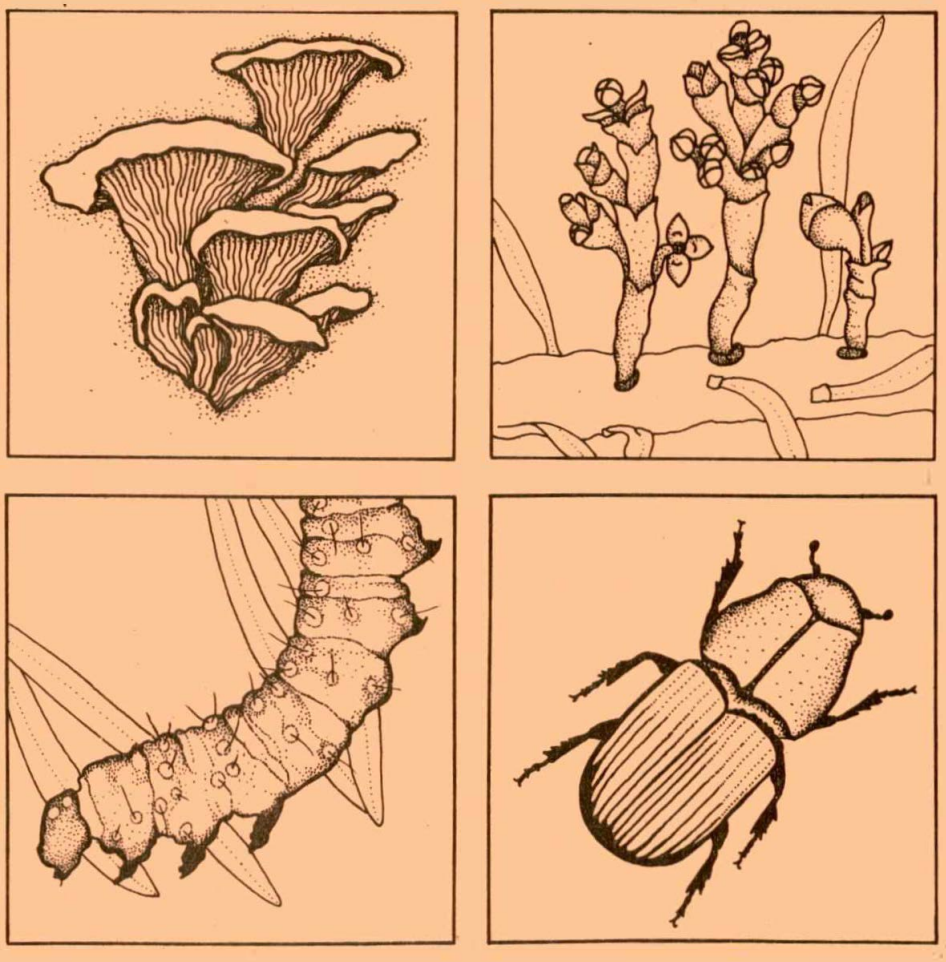

STATEWIDE MORTALITY ESTIMATES OF PONDEROSA PINE CAUSED BY MOUNTAIN PINE BEETLE FOR MONTANA IN 1980

INTRODUCTION

Aerial detection surveys in 1981 revealed that 76,393 acres of ponderosa pine type were infested with mountain pine beetle in Montana (fig. 1). A multistage remote sensing survey was conducted in 1981 to determine reliable estimates of the 1980 attacked trees which were recent faders visible on color photography. This was the first attempt in Montana to estimate losses in ponderosa pine caused by mountain pine beetle at the State level using multistage remote sensing techniques. Previous estimates using similar techniques for ponderosa pine losses in Montana were limited to the Lolo National Forest and adjacent private lands (Bousfield et al. 1973). Other attempts using remote sensing and multistage sampling include losses of ponderosa pine in the Black Hills of South Dakota, reported by Hostetler and Young in 1978. Mountain pine beetle loss estimates in lodgepole pine stands were obtained for the State of Montana using similar methods in 1979 (Bennett et al. 1980).

METHODS

Starting in mid-July aerial detection surveys were conducted for the ponderosa pine type. Using aerial detection sketch maps, which identified 1980 attacked ponderosa pine trees, the infested areas were displayed on one-half inch to-the-mile maps as polygons (fig. 2). An electronic planimeter was used to calculate acreages of each polygon to obtain total acreage infested by 5 ownership classes. These were National Forests, other Federal, State, private, and industrial private. One hundred photo plots of 90 acres each were planned for the survey. These were distributed equally throughout the infested areas by using the following formula:

$$I = \sqrt{\frac{\text{Acres infested}/640}{\text{Number of photo plots}} \times \text{Map scale inches/mile}}$$

I= Interval between planned photo plots in inches.

After the photo plot locations were determined, they were transferred to 1:80,000 black and white photography and 7-1/2-minute quad sheets for navigational purposes. This information was provided to a contractor who used a 12-inch focal length camera and SO 397 film to obtain 1:6,000 color photography. Photo triplets with 60 percent overlap were requested for each plot. The 100 plots, photographed between August 15 and September 7, were indexed and cut into respective stereo triplets. Photograph locations were to be within a 1/8-mile tolerance provided in the contract. Photo scale was checked using 7-1/2 minute quad sheets so that the correct grid scale was used to measure 90 acres on the ground.

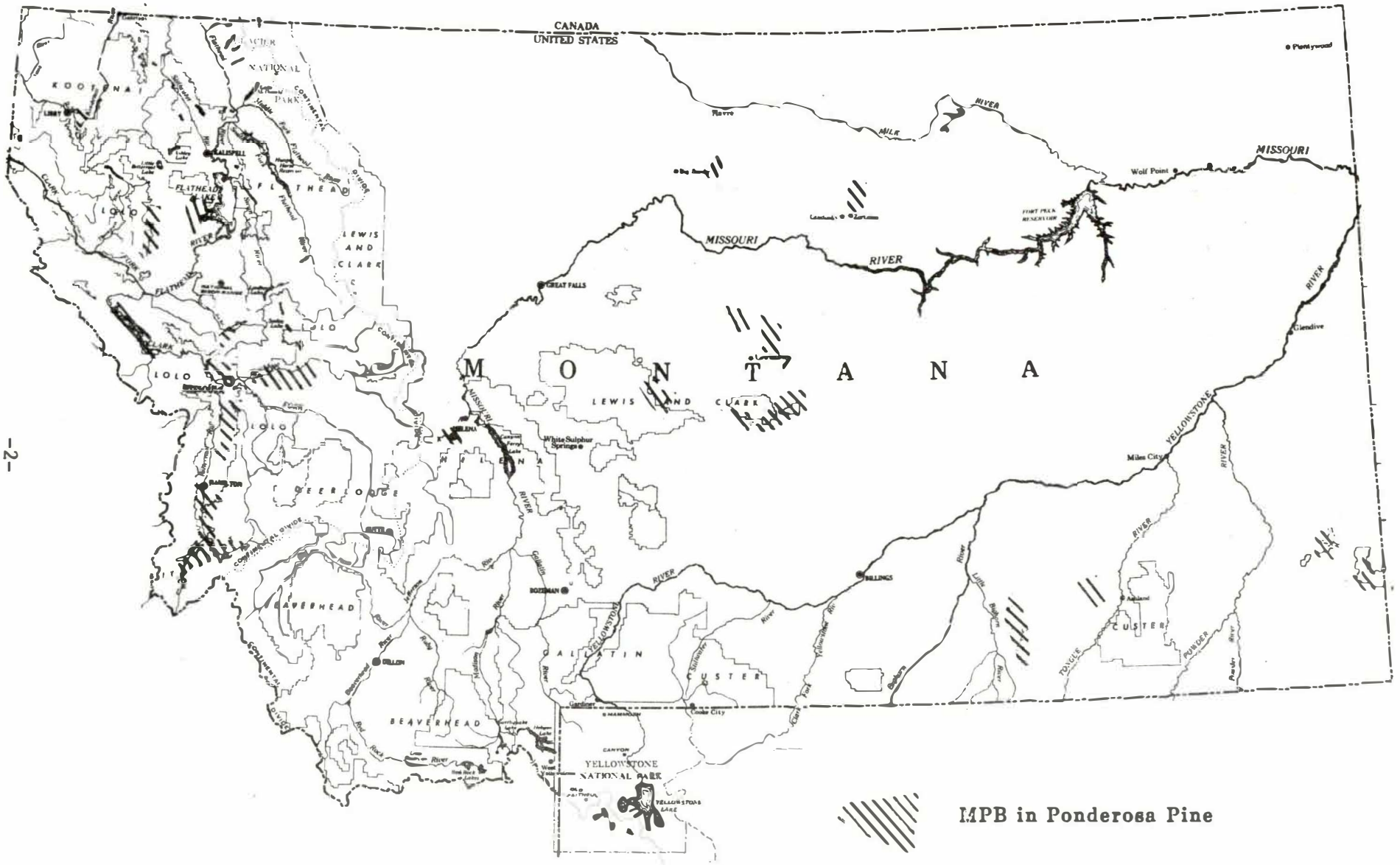

Figure 1.--Ponderosa pine type infested with mountain pine beetle in 1981.

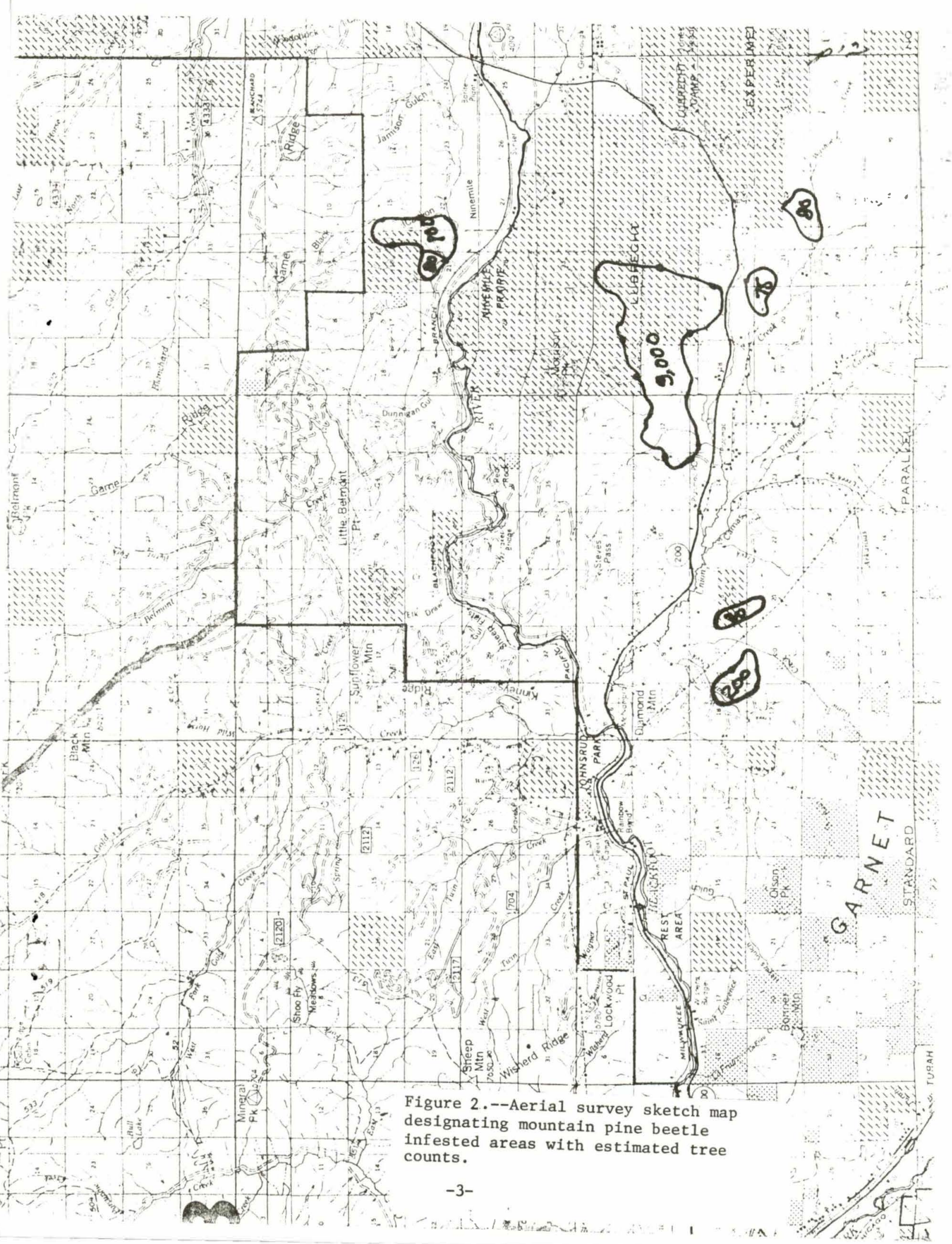

Figure 2.--Aerial survey sketch map designating mountain pine beetle infested areas with estimated tree counts.

Using the appropriate 90-acre grid (fig. 3) subdivided into thirty-six 2-1/2-acre subplots, the four corners were marked on the film so that the same area could be identified for ground truth plots. Each of the 100 photo plots were examined stereoscopically with a Bausch and Lomb zoom stereoscope to count fading trees in each of the 36 cells. Tree counts were recorded for each 2-1/2-acre cell and totals obtained for each 90-acre photo plot.

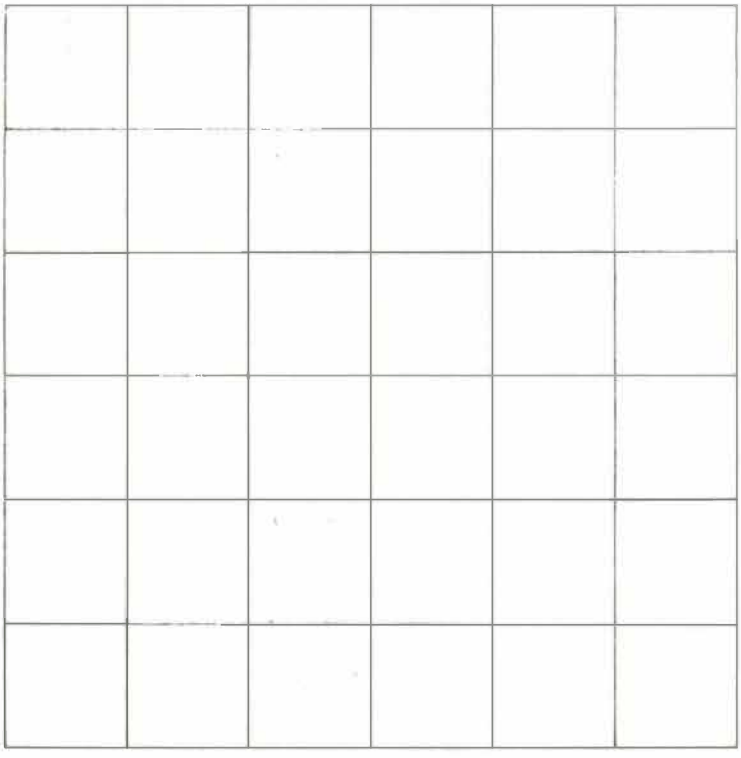

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Figure 3.--Grid scale used as primary sample unit.

After all 100 photographs were examined, 16 primary sample units (PSU) were selected by probability-proportional-to-size sampling (PPS). Two of the subcells within each selected PSU sample were then selected by PPS sampling for ground truth acquisition.

The two selected cells were identified on the film by using the appropriate grid and scribing the boundaries on the emulsion. Cell numbers were marked on the film so field crews would use the proper identification on the data sheet. Each cell was then visited in the field to

collect ground truth data. Black and white photographs 1:80,000 and 7-1/2-minute USGS quadrangle sheets were used to navigate to the approximate plot area. The 1:6000 color film with plot boundaries scribed was then placed in a hand-held stereo viewer which allowed the observer to find plot corners and boundaries. Features such as rocks, logs and faded trees could easily be seen for precise boundary placement. After boundaries were flagged the entire 2-1/2-acre plot was examined and all faded mountain pine beetle attacked trees were tallied by 1-inch diameter groups. Two sides of each 2-1/2-acre cell were measured for horizontal distance. This information was used to adjust for scale differences in area surveyed.

DATA ANALYSIS

Standard multistage estimation formulae was used to expand the data and to obtain statistical confidence limits for both trees and volume (Appendix I).

Tree height equations based upon diameters were developed from local data so that volume could be determined. From sample tree height data regression estimators were obtained by using log and inverse transformation to form the following equation. This transformation has proven to be a best fit for height diameter relationships.

$$Y = \left[\text{EXP} \quad A + B \frac{1}{DBH} \right]$$

When Y= Estimated tree height

DBH= Diameter of tree

Ponderosa volume equations found in the Region 1 Timber Sale Preparation Handbook were used to obtain cubic ft. volume based on diameter and height (Appendix II). Total volumes for each plot were then substituted into the multistage expansion equations to obtain volume estimates.

RESULTS

Survey estimates showed 32,534 ponderosa pine trees containing 216,987 cubic feet volume were killed in Montana in 1980. Mortality was scattered over 76,393 acres of ponderosa pine type throughout the State. Sampling errors of 8.57 percent for trees and 9.09 percent for volume were obtained (table 1). The relationship between photo interpretation counts and ground data produced an r^2 value of .93.

Mortality by ownership and sampling errors are shown in table 1.

Table 1. Mortality by Ownership

Ownership	Acres M	Number of faders M	Estimated ft3 volume M
National Forest	18.9	8.1	53.6
Other Federal	6.4	2.7	18.2
State	1.8	.7	5.1
Private	47.4	20.2	134.6
Industrial, private	1.9	.8	5.4
Total	76.4	32.5 ± 2.8 8.6%	216.9 ± 19.7 9.0%

DISCUSSION

All photographs were within the 1/8-mile tolerance as required by the contract. The average scale adjustment was .061 percent which produced a plot of 95.8 acres. Film development and delivery was 2 weeks later than expected. Ground truth data collection proceeded on schedule being completed by two 3-person crews in 2 weeks. Some of the usual problems of determining year of kill occurred but it was not a frequent problem. In a few cases Ips had attacked the trees but these were not tallied as killed by mountain pine beetle.

REFERENCES

Bennett, D., W. Bousfield, M. McGregor, and K. Gibson.
1979. Evaluation of multistage sampling techniques to measure lodgepole pine mortality caused by mountain pine beetle in Montana. USDA-Forest Service, Northern Region. S&PF Rpt. No. 80-13.

Bousfield, W. E., M. D. McGregor, and Steve Kohler.
1973. Mountain pine beetle impact survey on the Ninemile District, Lolo NF, and surrounding State and private lands. Insect and Disease Report, USDA-Forest Serv., Northern Region.

Hostetler, B. Bruce, and Robert W. Young.
1978. Estimation procedures for determining annual tree mortality caused by the mountain pine beetle. Forest Insect and Disease Management, S&PF, Rocky Mountain Region; Lakewood, Colorado. Rpt. No. 2-20.

Appendix I. Formulas and procedures used for determining multistage sampling estimates.

I. Notation.

Subscripts: $i = 1, \ldots, m$ denotes the sampled 90-acre photo plots.

$j = 1, \ldots, n$ denotes the 90-acre photo plots selected for ground sampling.

$k = 1, 2$ denotes the 2.5-acre subplots selected from each 90-acre photo plot.

A : Number of acres.

m : Number of photo plots sampled.

n : Number of photo plots selected for ground sampling.

xi : Number of faders counted in the i^{th} photo plot.

x : Total number of faders counted.

$$x = \sum_{i=1}^{m} x,$$

x_{jk} : Number of faders counted from the photo in the k^{th} subplot of the j^{th} photo plot

$\hat{Y}_{jk}$: Number of faders counted on the ground, in the k^{th} subplot of the j^{th} photo plot

$\hat{Y}_j$: Estimate of the number of faders in the j^{th} photo plot

$\hat{Y}$: Estimate of the number of faders

$S.E._{\hat{y}}$: Standard error of the estimate

$R.S.E._{\hat{y}}$: Relative standard error of the estimate,

$$R.S.E._y = \frac{S.E._{\hat{y}}}{\hat{Y}} .100, \text{ expressed as a percent}$$

II. Estimators

$$\hat{Y} = \left[\frac{A}{(90)\ (m)\ (n)} \right] \sum_{j=1}^{n} \hat{y}_j$$

where

$$\hat{y}_j = \frac{\left[\sum_{k=1}^{2} \frac{(x_j)\ (y_{ik})}{x_{jk}} \right]}{(x_{hj})\ (^{2})}$$

$$S.E._{\hat{y}} = \sqrt{\left[\frac{A}{(90)\ (m)} \right]^2 \frac{\sum_{j=1}^{m} \left(\hat{y}_j - \hat{Y} \right)^2}{n\ (n-1)}}$$

Since $\hat{Y}$ is the mean of the $\hat{y}_j$ values, the above formula can be reduced to the following more easily calculated form:

$$S.E._{\hat{Y}} = \sqrt{\left[\frac{A}{(90)\ (m)} \right]^2 \left[\frac{\sum_{j=1}^{m} \hat{y}_j^2 - \frac{\left(\sum_{j=1}^{n} \hat{y}_j \right)^2}{n}}{n\ (n-1)} \right]}$$

$R.S.E._{\hat{Y}} = \frac{S.E._{\hat{Y}}}{\hat{Y}} .100$, expressed as a percent.

R1-2430-31 (Revised 6/69)

REGION 1 VOLUME TABLES FOR ADP CRUISE COMPUTATIONS

TABLE PP 21

PONDEROSA PINE
CUBIC FOOT VOLUME

P.D. KEMP 1956
1 FT. STUMP TO 4" TOP DIB

DBH	TOTAL HEIGHT													
	040	050	060	070	080	090	100	110	120	130	140	150	160	170
6	1.6	2.0	2.4	2.8	3.2	3.6								
7	2.8	3.5	4.2	4.9	5.6	6.3								
8	4.1	5.1	6.1	7.1	8.2	9.2	10	11						
9	5.4	6.8	8.1	9.5	11	12	14	15						
10	6	8	11	13	15	17	19	21	23	25				
11	8	11	13	16	18	20	23	25	28	30				
12	10	13	16	19	22	25	28	30	33	36				
13	12	15	19	22	26	29	33	36	40	43				
14	14	18	22	26	30	34	38	42	46	50				
15	17	21	26	30	35	39	44	49	53	58	62			
16	19	24	30	35	40	45	50	56	61	66	71			
17	22	28	34	39	45	51	57	63	69	75	80			
18	25	31	38	44	51	58	64	71	77	84	90			
19	28	35	42	50	57	64	72	79	86	94	101			
20	31	39	47	55	63	71	80	88	96	104	112	120		
21	29	38	48	58	67	77	87	96	106	115	125	135		
22	33	43	54	64	75	85	96	106	117	128	138	149		
23	36	48	60	71	83	94	106	117	129	140	152	163		
24	41	53	66	78	91	103	116	128	141	154	166	179		
25	45	58	72	86	99	113	127	140	154	167	181	195	208	222
26	49	64	79	94	108	123	138	152	167	182	197	211	226	241
27	54	70	86	102	118	133	149	165	181	197	213	229	245	261
28	59	76	93	110	127	144	161	178	195	213	230	247	264	281
29	64	82	100	119	137	155	174	192	210	229	247	265	284	302
30	69	88	108	128	147	167	187	206	226	245	265	285	304	324
31	74	95	116	137	158	179	200	221	242	263	284	305	326	347
32	80	102	124	147	169	191	214	236	258	281	303	325	348	370
33	85	109	133	157	180	204	228	252	275	299	323	346	370	394
34	91	116	142	167	192	217	242	268	293	318	343	368	394	419
35	97	124	151	177	204	231	257	284	311	338	364	391	418	444
36	103	132	160	188	216	245	273	301	329	358	386	414	442	471
37	110	140	169	199	229	259	289	319	348	378	408	438	468	498
38	116	148	179	211	242	274	305	337	368	400	431	463	494	526
39	123	156	189	222	256	289	322	355	388	421	455	488	521	554
40		165	200	235	269	304	339	374	409	444	479	514	548	583
41		174	210	247	284	320	357	393	430	467	503	540	577	613
42		183	221	260	298	336	375	413	452	490	529	567	606	644
43		192	232	273	313	353	393	434	474	514	555	595	635	676
44		201	244	286	328	370	412	455	497	539	581	623	666	708
45			255	299	344	388	432	476	520	564	608	653	697	741
46			267	313	359	406	452	498	544	590	636	682	728	775
47			279	327	376	424	472	520	568	616	665	713	761	809
48			292	342	392	442	493	543	593	643	694	744	794	844
49			304	357	409	461	514	566	618	671	723	775	828	880
50				372	426	481	535	590	644	699	753	808	862	917
51				387	444	501	557	614	671	727	784	841	898	954
52				403	462	521	580	639	698	757	816	875	934	992
53				419	480	541	603	664	725	786	848	909	970	1031
54				435	499	562	626	690	753	817	880	944	1007	1071
55					518	584	650	716	782	848	914	980	1045	1111

CUBIC FOOT VOLUME FORMULAS BY DBH CLASSES

5 - 9" Vol. = X [0.4041(DBH) - 0.04535(DBH^2) + 0.001726(DBH^3) - 1.054732]

10 - 20" Vol. = 0.203X - 1.656

21" + Vol. = 0.218X - 9.637

$$X = \frac{(DBH)^2 (TOTAL\ HT.)}{100}$$